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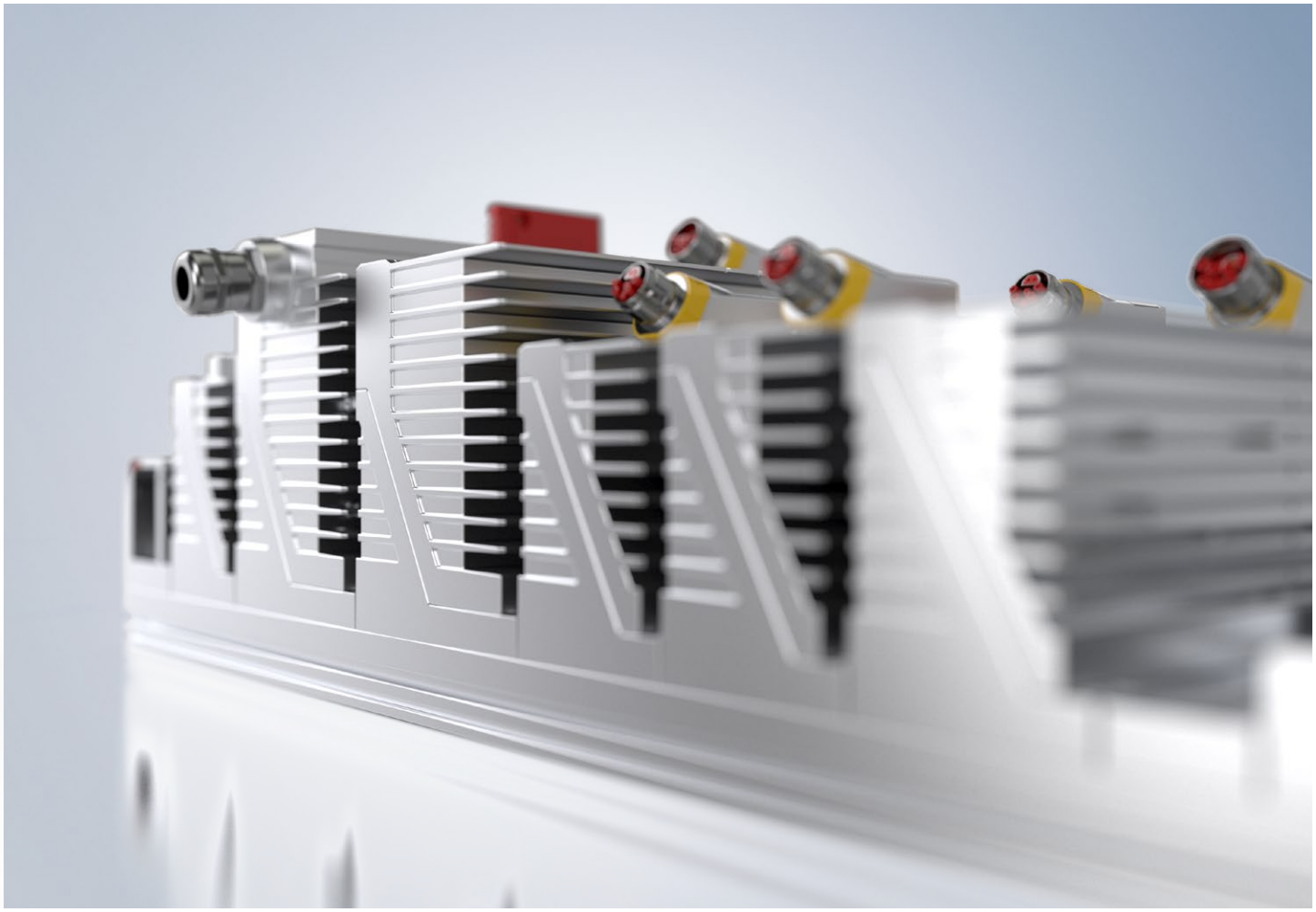


White paper

Goodbye control cabinet, hello future

How the innovative MX-System is revolutionizing automation in machine and systems engineering

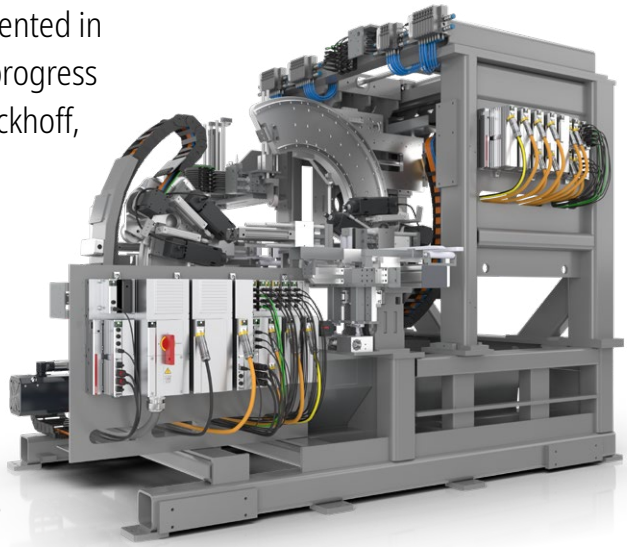
Machine and systems engineering companies are under increasing pressure to innovate. To compete successfully, you need to automate your products quickly and comprehensively, offer more customized solutions, and win over buyers around the globe with an environmentally and economically sustainable system footprint.

MX-System®

▶ www.beckhoff.com/mx-system

Given the current challenges, the concept of the control cabinet – which has remained largely unchanged for decades – is increasingly becoming a bottleneck. This is due to its limited flexibility and modularity in view of the greatly increased demands on the machines. In addition, the engineering and production processes for control cabinet projects are complex and barely automated. Apart from that, maintenance and servicing require experts, who are both expensive and hard to find.

The concept of the control cabinet must be reconsidered and implemented in new ways to ensure that progress is not slowed down. At Beckhoff, we have achieved this by developing a solution for control cabinet-free automation, the MX-System.



Example of a control cabinet-free machine module with integrated MX-System

History of the control cabinet

1895

The British electrical company Ferranti develops oil switches to minimize the risk of fire and accidents caused by sparks in electrical switchgear.

1903

A major fire breaks out at a plant in Bristol. The cause was a defective oil switch. This type of switch is surrounded by an oil-filled housing. Oil extinguishes the arcs that occur during switching. If the housing has a leak, gases can escape and ignite.

1908

The English engineer Henry Clothier develops a closed metal cabinet for switchgear to prevent disasters like the one in Bristol. The experts are not convinced by the new development at first.

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1930s

Even though metal-sheathed control cabinets are now increasingly being used, oil switches remain the standard until well into the 1930s.

1960s

The era of custom-made control cabinets is over. New suppliers are entering the market with standard control cabinets.

1980s

In addition to electrical systems, control cabinets are increasingly housing devices for system and machine control as well as the necessary data connections.

2000s

As electrification and digitalization advance, control cabinets face temperature and space issues. Systems are becoming ever larger, more complex, more expensive, and more wiring-intensive.

2010s

Control cabinet manufacturers are increasingly integrating more functions into their systems: devices are being digitally networked while components are becoming more compact and energy-efficient. Intelligent, demand-based cooling systems are replacing conventional air conditioning units, but often only allow limited savings in terms of space, energy, and costs.

2021

Beckhoff engineers develop and present a completely new approach. This allows the control cabinet system to be completely eliminated. This is proven over the following years in collaboration with pilot customers.

2025

Beckhoff launches the MX-System, a revolutionary series solution for control cabinet-free automation.

Top trends and challenges
for machine and systems engineering companies

Whether your company manufactures machine tools, production systems, or innovative conveyor technology, there are a handful of trends[1] that ultimately set the framework conditions for your company internationally.
Here is a brief overview of our top five.

TOP FIVE

#1 Pressure to innovate due to digitalization

The pace of automation in machine and systems engineering is accelerating. Following the acceleration of networking brought about by the expansion of the Industrial Internet of Things (IIoT), further milestones are now being achieved on the road to digitalization. The focus is on robotics and AI. Artificial intelligence algorithms require a comprehensive database. The challenges in engineering therefore involve recording and handling process data, including in the form of physical variables such as voltage, current, and temperature. Another challenge lies in creating digital twins for production simulation and modeling. In short, the pressure to achieve digital innovation is increasing and demands flexible, highly customized solutions.

#2 Shortage of skilled workers

The latest study[2] by an international personnel service provider confirms that 75 percent of companies worldwide are suffering from an acute shortage of skilled workers. The main driver is demographic change. After Japan, its impact is being felt particularly strongly in Germany. The German Economic Institute (IW)[3] forecasts that the German mechanical engineering industry will lose 296,000 skilled workers by 2034 due to retirement alone. However, only 118,000 new workers are expected to be hired in the same period. The bottom line is that the industry is short by 178,000 skilled workers.

[1] Cf. e.g.: https://www.eit.edu.au/power-ahead-with-mechanical-engineering-trends/ or https://www.mittelstand-heute.com/maschinenbau-2024-4-top-trends-und-herausforderungen
[2] Man Power Group, Global Talent Shortage 2024
[3] Cf.: https://www.elektroniknet.de/karriere/arbeitswelt/iw-studie-maschinenbau-droht-bis-2034-massiver-personalmangel.221781.html

#3 Globalization

Globalization continues to advance, not only on the market side but increasingly on the production side as well. A growing number of manufacturers are locating their production process in places where potential new customers can be found or where labor and energy costs are attractive, rather than producing exclusively or primarily in their home market. If you want to realize the potential savings effectively, you need machines and production solutions that meet high global standards and that can be used anywhere without major technical adaptations due to regulatory requirements.

#4 Sustainability and footprint minimization (ESG)

In the context of machines and systems, sustainability is a decisive competitive factor. This is true in terms of energy consumption and emissions during operation, as well as material and space consumption. This is why the footprint of machines and systems has been a compliance issue for some time. It is also becoming an increasingly important aspect for manufacturing companies due to ESG (Environment, Social, Governance) requirements. When assessing the value and attractiveness of a company, investors and rating agencies now apply ESG criteria rather than examining economic efficiency alone. These criteria are becoming increasingly important due to new political goals, such as those defined in the European Green Deal.

#5 Customization and short time-to-market

Off-the-shelf products are now almost impossible to sell in the machine and systems engineering market. Today's users demand solutions that are precisely tailored to their requirements and their spatial and manufacturing conditions on site. For you as a machine and systems engineering company, this means that your products must be designed in such a way that they can be quickly adapted to meet individual requirements. One way to achieve this is through modular concepts. In addition, new basic requirements are being added at an ever faster rate. The companies that can offer new developments that meet these requirements with a short time-to-market will secure a valuable competitive edge.

The control cabinet can be a limiting factor when dealing with the top trends

Up to now, for anyone wanting to develop solutions to meet the major challenges in machine and systems engineering, there has been no way to get around the control cabinet – and the way through it is becoming increasingly narrow. This is because the number of devices, relays, and cables that converge within it has been growing dynamically over the years. For quite some time, the control cabinet has been creating a bottleneck for automation and progress.

The following review shows how and why the control cabinet is now hindering progress when it comes to meeting the key challenges.

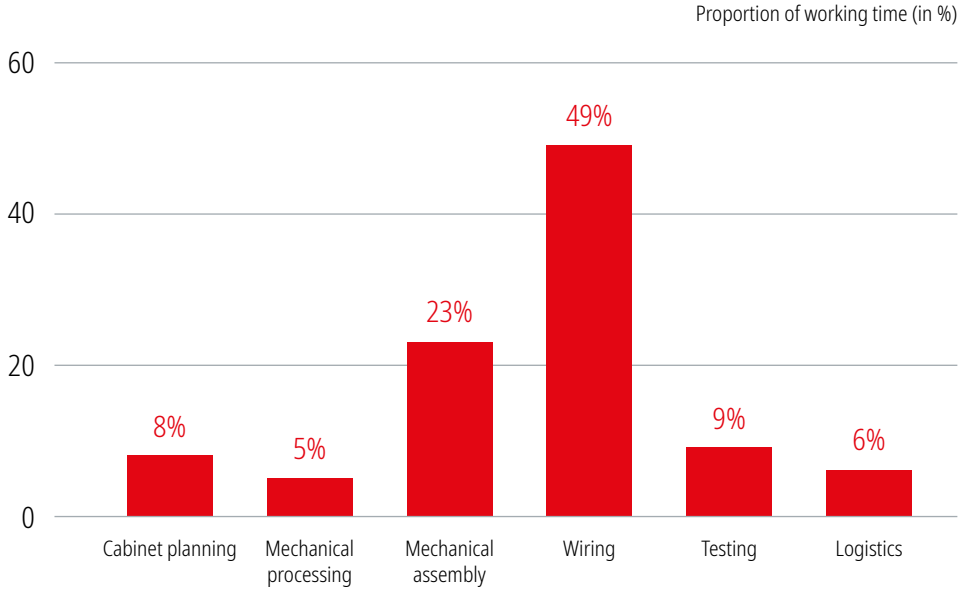
Digitalization and automation require larger control cabinets

The number of components installed in the control cabinet is growing. These additions range from new devices to the necessary fan and cooling units, as well as supplementary measurement and testing technologies. The latter need to be planned and installed separately when using conventional control cabinets. This is both labor-intensive and costly. What's more, each additional installation requires more space, especially as the defined minimum distances in relation to heat emission and temperature sensitivity must be maintained. As a result, control cabinets are becoming increasingly bulky, complex, and expensive.

As the complexity of control cabinets increases, so does the workload

The increasing complexity makes control cabinet construction more time-consuming and labor-intensive. For mechanical engineering companies, this means either accepting longer throughput times and lower productivity in production, or hiring additional skilled workers. In times of a shortage of skilled workers, however, this is hardly feasible on the scale required. The work has to be done with the available resources.

Take wiring, for example: It accounts for around 50 percent of the total time required to manufacture a control cabinet (see chart). Attempts to make wiring more efficient with the help of robots are still in their infancy. In addition, these concepts are very capital-intensive and ultimately only address the symptoms. Robots do not change the fact that the effort required to manufacture control cabinets continues to increase.



Proportion accounted for by the individual work steps in the total time required to manufacture and assemble a control cabinet.

Lack of international standards makes global marketing difficult

There are no globally applicable standards for the devices and components in the control cabinet. The same also applies to the structure as a whole. As a result, depending on the target market, manufacturers need to constantly adapt their control cabinets and check the product information and data sheets for all installed components individually, for example with regard to electrical and functional safety, as well as electromagnetic compatibility and immunity. Even for standard products, multiple variants of one and the same control cabinet are usually available today – for example, in accordance with UL, CSA, or IEC standards. This is time-consuming and expensive.

Developments in control cabinet design clash with ESG and sustainability goals

ESG and sustainability goals are becoming increasingly important in machine and systems engineering. And it all starts with the supply chain. As they contain a large number of components from different manufacturers, the supply chains for control cabinets are so complex that compliance with all ESG criteria can only be guaranteed with a great deal of effort that does not add value. And this complexity is increasing.

CSRD reporting and the ESPR Regulation are key concepts in this regard. The Corporate Sustainability Reporting Directive (CSRD), which has been in force since summer 2024, requires companies to disclose ESG aspects, including the sustainability of their own products. The measures will be tightened further from 2026 onwards in line with the Ecodesign for Sustainable Products Regulation (ESPR). This explicitly calls for sustainable product designs.

Another highly relevant aspect of sustainability is the space requirements for control cabinets. This is because the amount of hall space used by a production facility increases its resource consumption while also pushing up production costs. In addition, there is a lack of recyclability: When retrofitting the machine, it is only possible to recycle a small number of selected components at best. This does not include the copper cables used for the internal wiring.

Fixed installation spaces and lack of modularity are limiting factors

For machines and systems with a traditional control cabinet, it is very time-consuming to implement customized features. This is because all of the components that are not pre-assembled and installed as standard in the series control cabinet have to be planned, installed, and wired by hand in a complex and specific way for the relevant application. This takes time and requires human resources, both in development and production.

In addition, the installation space for extensions is limited, even though control cabinets are usually supplied with a space reserve and are therefore larger than necessary. Another stumbling block is the design principle. The control cabinet is not planned as a modular element, but as a central element, even for machine concepts with a modular mechanical design. Although multiple control cabinets are often used in these cases, a one-to-one modularity of control cabinet and machine module is never achieved. The result is merely an increase in the number of control cabinets, which multiplies the challenges described above.

Conclusion:
The control cabinet no longer has a future

In view of the current challenges, the control cabinet has long since reached its conceptual limits. After more than 100 years of continuous development, a fundamentally new and disruptive approach is needed.

MX-System fully integrated into the machine: Open mounting directly on the base frame simplifies wiring, improves accessibility, and replaces the control cabinet – a superior solution, especially in terms of design.

Revolutionary:
The MX-System for control cabinet-free automation

The new MX-System developed by Beckhoff is an innovative modular system that is superior to the control cabinet in terms of design. The MX-System is revolutionary because it enables control cabinet-free automation of machines and systems, opening up completely new possibilities in engineering.

Control cabinet-free automation was the development goal of the Beckhoff engineers. They presented the pioneering concept of the MX-System to the industry at the end of 2021. This was followed by a period of extensive testing, including in cooperation with customers from different industries and sectors, as well as in various implementation projects. The testing was successful, and the MX-System went into series production in mid-2025 as a future-oriented solution for control cabinet-free automation.

Modular and ingeniously easy to handle

The standout feature of the MX-System is its consistently modular design. It consists of a baseplate with slots and a modular system of various function modules. The connectors are standardized so that all of the modules are connected in the same way. All you need to do is choose the right modules for your application, attach them to the baseplate, and tighten the screws. That's it – you're ready to go. There is no need for a control cabinet. The MX-System is integrated into the machine or system and contains all of the switching technology – with optimal protection and the security of the IP67-rated housing design.

No manual wiring is required. To integrate electronic or electromechanical components using the function modules, each slot on the baseplate has up to two interfaces: A data interface integrates the component into the EtherCAT network and supplies it with 24 V DC or, as an option, 48 V DC. If required, the second interface supplies mains voltage of up to 480 V AC or DC voltage of up to 848 V, as may be needed for drives.

Everything is covered

The modular MX-System covers the entire range of tasks. The most important components include industrial PCs (IPCs) in all performance classes. These computers are the brains of a machine or system and control everything. There are also I/O modules for the necessary inputs and outputs, drive modules for controlling motors, relay modules for switching, and various system modules – for example for feeding in data or integrating additional power supplies and switches. All of the modules have a robust housing in accordance with IP65 or IP67. Detailed functionalities, such as cable protection for outgoing cables, are already integrated. This significantly reduces your workload and the number of components required.

The back of the system is particularly interesting for automation engineers, as each machine module has its own MX-System baseplate onto which the various function modules are attached and screwed.

Above all, however, the MX-System with its function modules enables a modular machine design from the outset. This is because the MX-System modules are integrated into the immediate vicinity of the sensors and actuators in the machine's installation space – right where they are needed. This reduces complexity and ensures the distances are kept short.

The disruptive aspect of the MX-System

It can completely replace the conventional control cabinet and opens up new and greater possibilities for machine and systems engineering companies when it comes to automation. No specialist knowledge is required. Once familiar with the principles of the MX-System, its potential can be fully and easily leveraged.

The answer to your challenges: MX-System®

	Control cabinet	MX-System
Complexity and sustainability	With each additional device, a control cabinet increases in installation space and complexity. This **requires space, resources, and energy**.	You can integrate the MX-System directly into the machine or system **in a sustainable and space-saving way**. There is no need for a control cabinet.
Shortage of skilled workers and effort	The manual project planning and wiring of all components requires **several skilled workers** and is **time-consuming and costly**.	You **do not need any specialists** for the MX-System. The function modules are simply plugged onto the baseplate. This saves time and **reduces the volume** of circuit diagrams and parts lists **by up to 80 percent**.
Customization and time-to-market	You need **at least 24 hours** to set up an individually configured control cabinet.	Setting up an MX-System with the same functions takes **about 1 hour**, including testing.
Globalization and standardization	When designing control cabinets, you must **ensure conformity** of the components used and the overall solution with market specifications.	In the MX-System, the modules **meet all standards** by design and are **IEC, UL, and CSA-compliant**.
Flexibility and short distances	In central control cabinet layouts, the **cable routes** become longer and more complex with each additional device. This **makes adjustments** and additional automation **more difficult**.	In the decentralized MX-System, the interfaces are pre-assembled. You can connect devices in the machine itself via connectors – with **short distances and installation times** and a high degree of flexibility.

Modular and scalable: The MX-System at a glance

With the MX-System from Beckhoff, the name says it all: The M stands for "modular" while X is the placeholder for the function modules in the modular system. These can be freely combined as required for maximum scalability. Each module combines all the parts and components required for a specific function in machine and systems engineering. All users need to do is choose the corresponding field devices. This significantly reduces the number of components and the engineering effort involved. Here is an overview.

Baseplates
- Mechanical mounting of function modules
- Electronic interface for energy and EtherCAT
- Diagnostic functions, interface for Bluetooth® dongle for diagnostics via mobile devices
- Scalability for every application due to different sizes and lengths

Drive technology
- Servo drives
- Variable frequency drives
- Direct and reversing starters
- Stepper motors
- STO/SS1, SafeMotion

Energy
- Supply
- Distribution
- Fuses
- Transforming
- Switching
- Measuring
- Buffering

Signals
- Digital
- Analog
- Position detection
- Communication
- Safety
- Pneumatic units

Controls/network
- Different performance classes for industrial PCs
- Ethernet
- EtherCAT
- Standard interfaces, such as USB and MiniDP

"In principle, every control cabinet is constructed in the same way. There is always a power supply, main switch, power supply units, the controller including I/O level and fieldbus, as well as the drive technology. There's also the power distribution, which refers to the switching of 400 V, the direct start of motors, or the supply of external units. We have standardized these recurring blocks and implemented them in a uniform concept in the form of the MX-System."

Daniel Siegenbrink
Product Management MX-System, Beckhoff Automation

Baseplates – the basis for control cabinet-free automation

- Three sizes for extensive scalability: one, two, or three-row baseplates with up to 32 slots per row
- Electrical and mechanical interfaces for each slot for connecting the function modules
- Baseplates in size 1 have data slots; from size 2, there are also slots for powerful drive, relay, or system modules
- Including connection options for potential equalization
- Integrated diagnostic functions, e.g. for temperature monitoring

IPC modules – the integrated heart of the control system

- Industrial PCs from Beckhoff specially optimized for the MX-System
- Large CPU portfolio for all performance classes and application profiles
- IPC modules control the function modules in the MX-System
- Optimized for all baseplate sizes with suitable slots for installation as master of the EtherCAT segment
- Equipped with typical industrial PC interfaces for Ethernet, EtherCAT, UPS, display connection, and USB

I/O modules – open to all signals in the automation environment

- Modules for the entire range of solutions in the Beckhoff I/O portfolio
- For all signal types in the current automation environment
- Large selection of modules for digital and analog inputs and outputs
- Special modules for tasks such as position detection, communication, safety, and the connection of compact drive solutions

Drive modules – for the entire range of drives

- Complete portfolio with compact multi-axis systems for all types of drives
- 1- and 2-channel variable frequency drives for controlling three-phase asynchronous motors
- Servo drives of various performance classes in 1- and 2-channel versions for controlling synchronous servomotors
- DC link power supplies for generating DC link voltage
- Capacitor modules for higher DC link capacity and energy efficiency

Relay modules – for switching high power levels

- For switching 1-phase and 3-phase AC loads with high power consumption
- For direct switching of 230 V AC, e.g., for fans and lighting
- Modules are versatile due to integrated I/Os
- For example, motor starter modules are available for starting three-phase asynchronous motors with mains voltage
- Integrated permanent monitoring of phase currents and integrated fuse protection for maximum line and short-circuit protection
- Control of heaters via solid state relays with temperature inputs for each channel

System modules – for flexible power distribution and fieldbus connection

- Module selection for tailored infrastructure extensions with the MX-System
- Solutions for a wide range of tasks: power infeed for power supply, EtherCAT connections, power output with line protection for voltages, power supplies, and Ethernet Switches
- Modules for an uninterruptible power supply (UPS)
- Extensions for connecting special control devices

Good to know

All MX modules comply with protection classes IP65 or IP67; aluminum or zinc die-cast housings protect the technology inside and prevent the ingress of dust and moisture. Due to the control cabinet-free, compact, and standardized design, MX-System layouts can be integrated directly into the installation space of your machines and systems. This offers visual appeal while also saving space and keeping cable runs short.

At a glance:
Benefits of the MX-System throughout the value chain

Design and engineering

With the MX-System, consisting of a baseplate and function modules, you benefit from a complete modular system for your automation tasks in machine and systems engineering. The pre-configured function modules are compact and combine all the necessary technical components in one housing. The advantage of the MX-System is that it allows you to implement almost any customization request or option, providing you with an electrical equipment kit that is at least as modular as your machine concept.

+ Greatly reduced number of components (average of 10 instead of 100)
+ 80% reduction in circuit diagrams and parts lists
+ Significantly less effort involved in design and project planning
+ 100% EtherCAT integration. The system is fully digital, with no passive components
+ No additional purchase of control cabinet housings, no design planning work, no outsourcing
+ Compliant with all standards and safety requirements worldwide (IP67, EMC, IEC, UL, CSA)
+ No additional space required, installation in or on the machine

Installation

The MX-System works according to the plug-and-play principle: Simply choose the required function modules, plug them onto a suitable baseplate, screw them in place, and plug in the cables. That's it – you're ready to go.

+ No manual mechanical work or assembly work required
+ No need for manual wiring – wiring errors are eliminated
+ Massively reduced set-up times due to plug-and-play – saves time and money
+ Devices and components are connected using hybrid cables
+ No special knowledge is required to plug in and screw the modules into place
+ No specialist electricians are required for installation

Goodbye control cabinet, hello future

▶ www.beckhoff.com/mx-system

This 14-meter Schirmer machine for the fully automatic processing of PVC window profiles is the first to replace all previously required control cabinets with the MX-System.

Ongoing operation at the customer's premises

The new MX-System from Beckhoff is significantly easier to service and maintain during operation than any previous control cabinet solution.

+ 100% EtherCAT integration: Users can perform system diagnostics on all modules, at any time
+ LED status indicators show the operating status of each individual module
+ A dedicated smartphone app reads the DataMatrix codes of the modules and provides all relevant diagnostic data. This means that faults can be identified and rectified by operating personnel themselves, without the need for a qualified electrician
+ Recyclability: The modules can be easily dismantled and reused in other MX-Systems, even internationally and following relocations, as they are fully compliant with standards
+ One function module replaces many conventional components. This means fewer components in purchasing and in the spare parts warehouse.

Beckhoff Automation –
Your partner for control cabinet-free automation

How can you enter the new MX-System world quickly, easily, and without much effort? The best way is a step-by-step approach in cooperation with the specialists from Beckhoff Automation. That's because we not only invented control cabinet-free automation with the MX-System, we also have a detailed understanding of your practical requirements based on decades of our own experience.

One contact for every inquiry

We are a long-established specialist in automation in machine and systems engineering and are at home in the world of control cabinets. This makes us an expert partner in all matters relating to automation technology.

We have become experts in control cabinet design through our own experience – it has been part of our daily business since our foundation in 1980. We can also take care of production on request. For many customers, this means we have been the central point of contact for electrical system solutions in the form of control cabinets. With the MX-System, we are now doing even more, opening up completely new perspectives and optimization potential with control cabinet-free automation.

Changeover made easy

You decide what impact the changeover to the MX-System will have on your existing production processes and routines.

The aim in developing the new system was clear from the outset: to completely replace conventional control cabinets without any restrictions in terms of modularity, scalability, or integration capability.

The MX-System can be used as a direct replacement for conventional control cabinets and can be flexibly integrated into new or existing system concepts, regardless of whether you are implementing new systems or retrofitting existing machines. Full realization of centralized, decentralized, and hybrid installation concepts is possible.

This makes the MX-System suitable both for a complete system changeover and for a step-by-step conversion, depending on the desired optimization depth of a machine.

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Would you like to find out more?

We are happy to help and look forward to hearing from you:

info@beckhoff.com

▶ www.beckhoff.com/mx-system

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